Inventory and Characterization of the Mammalian Fauna of the Sand Dunes of Guadalupe Mountains National Park, Texas

A Report
Submitted to:

Chihuahuan Desert Network
National Park Service

By:

Joel G. Brant & Clyde Jones

Department of Biological Sciences and Museum
Texas Tech University

1 March 2005

Address correspondence to:
Joel G. Brant
Museum of Texas Tech University
Fourth & Indiana Ave.
Box 43191
Lubbock, TX 79409-3191
Phone: (806) 742-2486
Fax: (806) 742-0362
joel.g.brant@ttu.edu

INVENTORY AND CHARACTERIZATION OF THE MAMMALIAN FAUNA OF THE SAND DUNES OF GUADALUPE MOUNTAINS NATIONAL PARK, TEXAS

Joel G. Brant and Clyde Jones

Department of Biological Sciences and Museum, Texas Tech University, Lubbock, Texas 79409

INTRODUCTION

Guadalupe Mountains National Park (GMNP) is a critical location for understanding the biogeographical and faunistic relationships among mammals in the Chihuahuan Desert. Situated along the Texas/New Mexico border, the national park includes a wide spectrum of representative habitats from desert lowlands to mountainous highlands. The diversity and importance of this area has been demonstrated through the publications generated by research efforts within the park (Gehlbach 1967, Wauer and Riskind 1977, Genoways and Baker 1979, Cornely et al. 1981, Wilhelm 1982). Situated at the base of the western escarpment of the Guadalupe Mountains in northern Hudspeth

County, Texas, are a series of gypsum and quartz dunes. Recently, GMNP has acquired approximately 10,000 acres of these dunes adjacent to the park (Fig. 1).

The sand dunes in this region of Texas are a result of the geological history of this area. The Sand Dune Complex of GMNP is located within the Salt Basin, a closed basin formed by the cumulative effect of drainage erosion from the several mountain ranges (Apache, Baylor, Cornudas, Delaware, Guadalupe, Pump Station Hills, Sierra Diablo, and Sierra Prieta) forming the basin boundary (Brand and Jacka 1979). As the basin periodically flooded, it would deposit sediment from the surrounding mountains along the shores of Linda Lake (Wilkins and Currey 1999). This sediment would then be picked up by the western winds and blown east. As the slope of the landscape increased, the carrying capacity of the wind decreased, resulting in the wind dropping its sediment load (Machenberg 1984). Over millennia, these collections of sediment grew to become the quartz dunes present today. Due to the high evaporation rate and the lack of outflow for Linda Lake, the water would slowly evaporate thereby concentrating the dissolved particles. Eventually, gypsum deposits formed on the shores of Linda Lake and were similarly carried away by westerly winds (Wilkins and Currey 1999). Over millennia, these became the gypsum dunes present today.

There have been several surveys of the mammalian fauna of GMNP. Bailey (1905) provided the first accounts of mammalian activity in the Guadalupe Mountains of Texas, and Davis (1940) conducted the first systematic survey of the area. Genoways et al. (1979) completed the most complete systematic survey of mammals in GMNP. Many of these surveys concentrated on the mountainous regions of the park and their relationships to other mountain ranges in southeastern New Mexico and Trans-Pecos

Texas. To date, there have been few studies that have examined the mammalian fauna of the lower desert regions of the park, in particular the sand dune areas. Scudday (1977) reported on vertebrates from these dunes, including mammals, and West (1985) and Stangl (1992) provide further observations on mammals in this area.

Our study began in October 2003 and includes data collected through February 2004. The purposes of this study were: 1) to determine the occurrence of mammal species in the Sand Dune Complex, 2) to estimate the relative abundance of small mammal species, 3) to establish permanent, georeferenceable sampling sites. The information gathered in this study is valuable as baseline data for future studies of biodiversity and detection of change at GMNP and western Texas.

MATERIALS AND METHODS

The sand dunes at the Sand Dunes Complex, GMNP, were divided into four generalized dune categories based on sand particle composition and vegetative component (Fig. 2). Two of the dunes categories were in response to the presence of quartz based “Red” dunes and gypsum based “White” dunes. The dunes that separated the red and white dunes were designated as the Intergrade Dunes. Finally, the layer of sand that surrounds both dune fields was designated as the Cover Sands. Sampling was carried out in these dune categories for small mammal relative abundance studies presented later in this report under Community Interactions.

The quartz based Red Dunes of the Sand Dunes Complex, GMNP, are the more northerly of the two dune fields in the complex (Fig. 2). Wilkins and Currey (1999) determined that the quartz dunes of GMNP were generally older than the adjacent

gypsum dunes. This observation is supported by the lack of truly active, shifting dunes and the predominance of semi-stabilized vegetated dunes. The dominant vegetation in these dunes is a mesquite (*Prosopis* sp.) scrub with scattered grasses. Two trap lines of 50 Sherman live traps were set heading north from the edge of the Red Dunes area and continuing for about 500 meters deeper into the dune area.

The gypsum based White Dunes of the Sand Dunes Complex, GMNP, are the more southerly of the two dune fields in the complex (Fig. 2). The gypsum dunes contain both semi-stabilized vegetated dunes dominated by yucca scrub vegetation with scattered grasses and actively, aeolian shifting dunes that are mostly devoid of vegetation. One trap line of 50 Sherman live traps was set heading roughly southeast across the active dunes and another line of 50 Sherman live traps was set heading roughly south through the vegetated portion of the White Dunes.

Most of the eastern side of the Salt Basin is covered with a three-foot layer of eolian sand. This relatively flat region surrounds the Sand Dune Complex and is much older than the other dune categories. This habitat has been designated the Cover Sands and is dominated by cactus and desert scrub vegetation. One trap line of 50 Sherman live traps was set heading roughly west from the access road about half a mile from the parking area. Another trap line of 50 Sherman live traps was set heading south from the post next to the access road roughly a quarter mile from the parking area.

Between the Red and the White Dunes is an area where both grains of sand occur. This area was designated the Intergrade Dunes, and is an area where species may move between the dune communities. The area is physically similar to the Cover Sands, with a dominant vegetation of desert scrub with lots of cactus. Two parallel trap lines of 50

Sherman live traps were set heading roughly east between the two dune fields. Each line was set approximately 50 meters from the edge of the dune field.

Standard techniques for sampling small to medium-sized species were utilized to survey the mammalian fauna (Jones et al. 1996, Animal Care and Use Committee 1998). Three trap lines consisting of 50 Sherman live traps were set in a pace-line method (10 meter intervals between traps) within each dune category to sample the rodent populations. Pocket gophers were sampled opportunistically using McAbee gopher traps. Spotlighting at night was utilized to sample species that are difficult to sample by trapping. Large mammals were recorded by sightings or other sign. Voucher specimens were prepared as museum study skins and skeletons and deposited in the Natural Science Research Laboratory (NSRL) of the Museum of Texas Tech University (TTU). Frozen tissue samples for most specimens were also deposited in the Collection of Frozen Tissues, NSRL, TTU.

Relative abundance for small rodents was estimated using capture indices (Conroy 1996) based on the number of individual animals captured per unit of time and effort (e.g., trap night). Individuals to be released were marked by removing the lateral toe of the right hind foot to record recapture rate. A total of 2000 trap nights were conducted for this survey. Each dune category was sampled for 500 trap nights. Shannon's Diversity Index (Pielou 1975) estimates for each of the dune categories and season, were calculated using the total number of species and the capture index per species. Pairwise *t*-tests based on randomizations of the capture index per species were conducted to test for significance in diversity values between dune category and season.

SPECIES ACCOUNTS

The presence of 4 orders and 11 families of mammals were recorded during this study at the Sand Dunes Complex of Guadalupe Mountains National Park. In the following accounts, 23 species native to the Sand Dunes Complex area are treated. Scientific names and arrangement of species follow Baker et al. (2003) and all subspecific designations are according to Hall (1981). Common names follow Wilson and Cole (2000).

ORDER LAGOMORPHA--RABBITS, HARES, AND PIKAS

Family Leporidae--Rabbits and Hares

Sylvilagus audubonii neomexicanus

Desert Cottontail

The desert cottontail is a very common species in the western half of the state (Schmidly 2004). In the Trans-Pecos, they prefer open desert scrub associations (Schmidly 1977). In the Guadalupe Mountains, this species is very common in the lowland desert portions as well as the foothills (Genoways et al. 1979). Scudday (1977) listed this species as one of the most visible mammals in the dunes area. West (1985) reported that this species was encountered at a lower frequency than *Lepus californicus* and was more common in the Red Dunes. Stangl (1992) also reported that this species was very abundant and was most likely to be seen during the early evening hours. No specimens were collected during the current survey. As with previous studies, this species was frequently sighted throughout the survey.

Lepus californicus texianus

Black-tailed Jackrabbit

The jackrabbit is distributed throughout much of the state and is common in the dry western portions of Texas (Schmidly 2004). They prefer open areas of desert scrub or mesquite grasslands in the Trans-Pecos (Schmidly 1977). In the Guadalupe Mountains, this species is very common in the lowland desert portions as well as the foothills (Genoways et al. 1979). Scudday (1977) listed this species as one of the most visible mammals in the dunes area. Both West (1985) and Stangl (1992) report frequent sightings and other evidence of this species presence, such as tracks and scat throughout the dunes area. No specimens were collected during the current survey. As with previous studies, this rabbit was frequently sighted in the Red and White dunes as well as the Cover Sands and Intergrade Dunes.

Additional records (1): Lewis Well (TTU 19990).

ORDER RODENTIA--RODENTS

Family Sciuridae--Squirrels

Spermophilus spilosoma marginatus

Spotted Ground Squirrel

This species occurs throughout the western half of Texas and prefers dry, sandy soils (Schmidly 2004). Genoways et al. (1979) collected individuals from the gypsum dunes near Lewis Wells and noted that this species apparently is restricted to the desert lowlands of the western areas of the park. Scudday (1977) listed this species as one of the most visible mammals in the sand dunes area. West (1985) observed the spotted ground squirrel around Dell City to the west and along U.S. 62/180 to the south, but

failed to find it in the dunes area. Stangl (1992) noted that the characteristic alarm calls were never heard during March though he collected two individuals, while these alarm calls were commonly heard and this species was commonly seen during August. This species was not seen or heard during this survey, but that is most likely due to the late fall and winter time frame of the survey.

Additional records (5): 1.44 mi. N, 4.5 mi. W Guadalupe Peak (TTU 20006); Lewis Well, 4 (TTU 20007-20010).

Family Geomyidae--Pocket Gophers

Cratogeomys castanops parviceps

Yellow-faced Pocket Gopher

This large pocket gopher only occurs throughout the Trans-Pecos in a variety of soil types (Schmidly 1977). *Cratogeomys castanops* generally prefers deep, mellow soils, but will occupy sandy areas in the absence of other species of pocket gopher (Schmidly 2004). Genoways et al. (1979) only collected this species from areas with firmly packed gypsum and quartz sands. Scudday (1977), West (1985), and Stangl (1992) all report numerous mounds in the Sand Dunes Complex. Stangl (1992) also noted that there were fewer mounds during August, suggesting a reduction in activity during the warm portions of the year. Five yellow-faced pocket gophers were collected during this survey. Three females were collected from the cover sands area during December and February. Two additional females were collected from the intergrade dunes area on 24 January 2004. Both the cover sands and intergrade dunes consist of relatively flat, packed layers of both quartz and gypsum sands, which supports the

observations of Genoways et al. (1979) concerning the preferred habitat for this species in GMNP.

Specimens examined (5): Intergrade Dunes, 2(TTU 100022-100023); Cover Sands, UTM-13R-501199E-3532425N (TTU 100024); Cover Sands, UTM-13R-500279E-3532040N (TTU 100021); Cover Sands, UTM-13R-500065E-3531754N (TTU 100020).

Additional records (3): 1.38 mi. N, 4.25 mi. W Guadalupe Peak, 2 (TTU 23289-23290); Lewis Well (TTU 20014).

Family Heteromyidae--Pocket Mice, Kangaroo Rats, and Kangaroo Mice

Perognathus merriami gilvus

Merriam's Pocket Mouse

This species occurs throughout the central portions of Texas and reaches the northwestern limit of its range in the Panhandle and Trans-Pecos regions. This species prefers soil types ranging from sandy to gravelly that are sparsely vegetated (Schmidly 2004). Scudday (1977) did not list this species as occurring in the area, and West (1985) and Stangl (1992) both list this species as possibly occurring in the dunes complex. Merriam's pocket mouse was captured twice during this survey from the vegetated gypsum dunes of the Sand Dunes Complex. This species probably occupies a minor role in the community structure of the Sand Dunes Complex.

Specimens examined (1): Vegetated Gypsum Dunes, UTM-13R-501003E-3532027N (TTU 100238).

Additional records (1): Lewis Well (TTU 20109).

Chaetodipus eremicus eremicus

Chihuahuan Desert Pocket Mouse

The Chihuahuan Desert pocket mouse is found primarily in the lower desert environments of the Trans-Pecos and prefers sandy or soft alluvial soils (Schmidly 2004). It is especially abundant along stream bottoms and washes (Schmidly 1977). Genoways et al. (1979) reported that this species was most common on the western lowland desert sections of the national park. Scudday (1977) reported this species to have very high abundances in the dunes area and West (1985) reported seeing several individuals. Stangl (1992) failed to record this species from the dunes area but listed it as probably present. This species was the second most abundant rodent encountered during this survey, with 41 individuals captured and 13 specimens collected. *Chaetodipus eremicus* was the second most captured species in every dune category.

Specimens examined (13): Red Dunes, UTM-13R-501633E-3532906N (TTU 100012); Intergrade Dunes, UTM-13R-501918E-3531865N (TTU 100011); Active Gypsum Dunes, UTM-13R-501387E-3532368N, 2 (TTU 100003, 100293); Vegetated Gypsum Dunes, UTM-13R-501213E-3532377N (TTU 100014); Vegetated Gypsum Dunes, UTM-13R-501003E-3532027N (TTU 100013); Cover Sands, UTM-13R-500514E-3532293N (TTU 100010); Cover Sands, UTM-13R-500467E-3532216N, 3 (TTU 100007-100009); Cover Sands, UTM-13R-500281E-3532031N (TTU 100006); Cover Sands, UTM-13R-500270E-3532029N, 2 (TTU 100004-100005).

Additional records (4): 1.44 mi. N, 4.5 mi. W Guadalupe Peak (TTU 20060); 0.5 mi. N, 4.75 mi. W Guadalupe Peak (TTU 23319); Lewis Well, 2 (TTU 20085-20086).

Dipodomys merriami merriami

Merriam’s Kangaroo Rat

This species occurs throughout the Trans-Pecos and is one of the most common rodents in this region (Schmidly 1977). Merriam's kangaroo rat is a habitat generalist and is equally successful on sandy, gravelly, or rocky soils (Schmidly 2004). Where *D. merriami* and *D. ordii* are sympatric, *D. merriami* usually occurs on the more gravelly soils while *D. ordii* occupies the sandy soils (Schmidly 1977). Scudday (1977), Stangl (1992), and West (1985) all report that this species has a high abundance in the Sand Dune Complex. West (1985) suggests that this species is more prevalent in the Red Dunes, while Stangl (1992) noted that it is more common on the surrounding cover sand. Merriam's kangaroo rat was the most abundant rodent encountered during this survey with 76 individuals captured and 29 specimens collected. This species was the most abundant rodent in every dune category, with the exception of the White Dunes. *Dipodomys merriami* showed a definite preference for the Cover Sands area where it accounted for roughly 74% of the individuals captured. Two scrotal males were encountered during February.

Specimens examined (29): Red Dunes, UTM-13R-501780E-3532933N (TTU 100047); Red Dunes, UTM-13R-501633E-3532906N (TTU 100045); Red Dunes, UTM-13R-501900E-3532902N (TTU 100049); Red Dunes, UTM-13R-501871E-3532873N (TTU 100048); Red Dunes, UTM-13R-501697E-3532805N (TTU 100046); Red Dunes, UTM-13R-500516E-3532284N, 2 (TTU 100043-100044); Intergrade Dunes, UTM-13R-501806E-3532459N (TTU 100040); Intergrade Dunes, UTM-13R-501391E-3532405N (TTU 100038); Intergrade Dunes, UTM-13R-501809E-3532304N (TTU 100041); Intergrade Dunes, UTM-13R-501793E-3531928N (TTU 100039); Intergrade Dunes, UTM-13R-501918E-3531865N (TTU 100042); Active Gypsum Dunes, UTM-13R-

501393E-3532372N (TTU 100025); Vegetated Gypsum Dunes, UTM-13R-501213E-3532377N (TTU 100052); Vegetated Gypsum Dunes, UTM-13R-501169E-3532371N (TTU 100051); Vegetated Gypsum Dunes, UTM-13R-501284E-3532321N (TTU 100053); Vegetated Gypsum Dunes, UTM-13R-500715E-3532260N (TTU 100050); Cover Sands, UTM-13R-500197E-3532561N, 4 (TTU 100028-100031); Cover Sands, UTM-13R-501263E-3532402N (TTU 100037); Cover Sands, UTM-13R-500514E-3532293N (TTU 100036); Cover Sands, UTM-13R-500467E-3532216N (TTU 100035); Cover Sands, UTM-13R-500279E-3532040N (TTU 100034); Cover Sands, UTM-13R-500270E-3532029N, 2 (TTU 100032-100033); Cover Sands, UTM-13R-500045E-3531833N, 2 (TTU 100026-100027).

Additional records (38): 1.44 mi. N, 4.5 mi. W Guadalupe Peak, 6 (TTU 20319-20324); 0.5 mi. N, 4.75 mi. W Guadalupe Peak, 8 (TTU 20325, 23427-23433); 0.5 mi. N, 4.5 mi. W Guadalupe Peak, 6 (TTU 23434-23439); Lewis Well, 18 (TTU 20376-20392, 23477).

Dipodomys ordii ordii

Ord's Kangaroo Rat

This kangaroo rat occurs throughout the western half of Texas and prefers areas where shifting sands are the dominant substrate type (Schmidly 2004). As stated above, where *D. merriami* and *D. ordii* are sympatric, *D. merriami* usually occurs on the more gravelly soils, while *D. ordii* occupies the sandy soils (Schmidly 1977). Scudday (1977) reported that both kangaroo rat species were equally abundant in the Sand Dune Complex. West (1985) stated that *Dipodomys ordii* appeared to be more common in the non-gypsum dune areas, while Stangl (1992) noted that this species was the most

abundant rodent in the dunes and surrounding sand flats. During this survey, 19 *Dipodomys ordii* were captured and 11 specimens were collected from the Sand Dunes Complex. Ord's kangaroo rat was most abundant on the White Dunes and less abundant on the Red Dunes and Intergrade Dunes. This species was absent from the surrounding Cover Sands. A single reproductive male was collected on 25 January 2004.

Specimens examined (11): Red Dunes, UTM-13R-501633E-3532906N (TTU 100061); Red Dunes, UTM-13R-501871E-3532873N (TTU 100062); Intergrade Dunes, UTM-13R-501776E-3532221N (TTU 100058); Intergrade Dunes, UTM-13R-501793E-3531928N (TTU 100059); Intergrade Dunes, UTM-13R-501918E-3531865N (TTU 100060); Active Gypsum Dunes, UTM-13R-501393E-3532372N (TTU 100056); Active Gypsum Dunes, UTM-13R-501387E-3532368N, 2 (TTU 100054-100055); Active Gypsum Dunes, UTM-13R-501869E-3532343N (TTU 100057); Vegetated Gypsum Dunes, UTM-13R-501169E-3532371N (TTU 100064); Vegetated Gypsum Dunes, UTM-13R-501003E-3532027N (TTU 100063).

Additional records (46): 2.88 mi. N, 7.88 mi. W Guadalupe Peak, 3 (TTU 20419-20421); 1.44 mi. N, 4.5 mi. W Guadalupe Peak, 6 (TTU 20319-20324); 1.38 mi. N, 4.25 mi. W Guadalupe Peak (TTU 23507); 0.5 mi. N, 4.75 mi. W Guadalupe Peak, 20 (TTU 20422-20423, 23480-23497); 0.5 mi. N, 4.5 mi. W Guadalupe Peak, 6 (TTU 23434-23439); 7.75 mi. W Guadalupe Peak (TTU 20424); Lewis Well, 5 (TTU 20433-20437).

Family Muridae--Rats, Mice, Voles, Gerbils, Hamsters, and Lemmings

Reithrodontomys megalotis megalotis

Western Harvest Mouse

This relatively uncommon species occurs throughout the Panhandle and Trans-Pecos regions of Texas (Schmidly 2004). The preferred habitats for the western harvest mouse are areas with dense grass, weeds, and brush (Schmidly 1977). In the Guadalupe Mountains this species is most common at moderate to high elevations in areas with grass (Genoways et al. 1979). Scudday (1977) collected a specimen (SRSU 1794) of the western harvest mouse from an area of sacaton grass to the south of the gypsum dunes. This species was not encountered during this study.

Peromyscus eremicus eremicus

Cactus Mouse

This species occurs throughout the Trans-Pecos and generally prefers rocky habitats in the lowland desert (Schmidly 1977). Genoways et al. (1979) and Cornely et al. (1981) determined that this species has its greatest abundance in the rocky slopes in the foothills of the Guadalupe Mountains. Scudday (1977), West (1985), and Stangl (1992) did not list this species as possibly occurring in the dunes area. Two specimens were collected from the active portion of the White Dunes in the Sand Dunes Complex. One male was collected on 16 November 2003 and another male on 25 January 2004. These specimens represent the first records of this species in the Sand Dunes Complex.

Specimens examined (2): Active Gypsum Dunes, UTM-13R-501393E-3532372N (TTU 100255); Active Gypsum Dunes, UTM-13R-501387E-3532368N (TTU 100254).

Peromyscus leucopus tornillo

White-footed Mouse

The white-footed mouse is one of the more common species in Texas, with a statewide distribution and generally prefers woodlands, though they have a wide

tolerance to habitats (Schmidly 2004). In the Guadalupe Mountains, this species is not common but occurs primarily in the lowland desert scrub associations (Cornely et al. 1981, Genoways et al. 1979). Scudday (1977), West (1985), and Stangl (1992) did not list this species as possibly occurring in the dunes area. No specimens were collected during the current survey. This species is included as occurring in the Sand Dunes Complex based on a single individual collected from gypsum and quartz sands near Lewis Well (Cornely et al. 1981, Genoways et al. 1979).

Additional records (1): Lewis Well (TTU 20621).

Peromyscus maniculatus blandus

Deer Mouse

The deer mouse is another very common species in Texas with a statewide distribution. This species generally inhabits grasslands or areas of open brush (Schmidly 2004). In the Guadalupe Mountains this species is the most common lowland desert rodent with preferences for areas with few rocks (Cornely et al. 1981, Genoways et al. 1979). Scudday (1977) listed this species as occurring in the dunes area and West (1985) listed it as a species that possibly occurs in the area. Specimens of the deer mouse from the Sand Dunes Complex were not collected by Stangl (1992) or during the current study. Genoways et al. (1979) and Cornely et al. (1981) lists two individuals captured at Lewis Well, but stated that they were captured in an area of desert scrub.

Additional records (2): Lewis Well, 2 (TTU 20622-20623).

Onychomys arenicola arenicola

Mearns's Grasshopper Mouse

This species occurs throughout the Trans-Pecos, and usually occurs in lowland desert associations containing sandy or gravelly soils and desert scrub vegetation (Schmidly 2004). Genoways et al. (1979) stated that this species is abundant in the desert lowlands. Stangl (1992) collected two individuals from the cover sands area surrounding the dune fields. Two specimens were collected during the current survey from the Intergrade Dunes and on the leading edge of the active portion of the White Dunes. Scudday (1977) does not list this species as occurring in the dune complex, but does record the collection of an *Onychomys leucogaster* in the Red Dunes area. This record of *O. leucogaster* is suspect due to the presence of *O. arenicola*, with whom it usually exhibits a mutually exclusive local distribution (Stangl 1992). In addition, *O. leucogaster* has not been reported from west of the mountains that make up the Front Range of Texas (Genoways et al. 1979, Stangl et al. 1994).

Specimens examined (2): Intergrade Dunes, UTM-13R-501391E-3532405N (TTU 100188); Active Gypsum Dunes, UTM-13R-501869E-3532343N (TTU 100187).

Additional records (7): 1.375 mi. N, 4.25 mi. W Guadalupe Peak, 5 (TTU 23640-23644); Lewis Wells, 2 (TTU 20503-20504).

Sigmodon hispidus texianus

Hispid Cotton Rat

The hispid cotton rat is perhaps one of the most abundant rodents in Texas. It has a statewide distribution and prefers tall grassy habitats (Schmidly 2004). In the Trans-Pecos, this species is usually encountered along river bottoms or moist streambeds that provide sufficient grass for them to build their runways (Schmidly 1977). In the Guadalupe Mountains, this species is most common at low to moderate elevations on the

eastern slope of the mountains (Genoways et al. 1979). Scudday (1977), West (1985), and Stangl (1992) did not list this species as possibly occurring in the dunes area. This species is included as occurring in the Sand Dunes Complex based on a single individual collected from near Lewis Well (Genoways et al. 1979).

Additional records (1): Lewis Well (TTU 20653).

Neotoma leucodon robusta

Eastern White-throated Woodrat

This species occurs throughout the Trans-Pecos and is usually associated with rocky slopes at intermediate elevations (Schmidly 1977). Genoways et al. (1979) determined that this species occurs along the perimeter of the Guadalupe Mountains and can extend out into the surrounding lowland desert. Neither Scudday (1977) nor the current survey encountered this species and West (1985) merely listed it as possibly occurring in the Sand Dune Complex. Stangl (1992) collected two adult males from the sand flats (= cover sands) surrounding the dune fields and attributed them to an established population as opposed to incidentally dispersing individuals. Cornely (1979) demonstrated that species of *Neotoma* that occur sympatrically exhibit microallopatry through mutually exclusive habitat partitioning. However, Cornely (1979) also stated that the distribution of *Neotoma leucodon* is most likely limited by the presence of other species of woodrat more than by habitat limitations. Based on this statement and the observations of Stangl (1992) and this survey on the abundance of other species of woodrats, it would appear that *Neotoma leucodon* could be expanding its range into the sand dunes.

Additional records (1): Tank Hill, 1.44 mi. N, 4.5 mi. W Guadalupe Peak (TTU 23677).

Neotoma micropus micropus

Southern Plains Woodrat

This species occurs throughout the western half of Texas and prefers thorny brushlands (Schmidly 2004). Scudday (1977) did not report this species, but West (1985) tells of seeing an individual along U.S. 62/180. Stangl (1992) captured a single adult, and noted that the semi-stabilized vegetated dunes appeared to provide ample habitat for this species. Two individuals were collected from the Sand Dunes Complex during the current survey. A male and a female *Neotoma micropus* were collected during October 2004 from the Cover Sands and the Red Dunes respectively. As stated above, the low abundance of this species may be contributing to the apparent expansion of *Neotoma leucodon* into the sand dunes area.

Specimens examined (2): Red Dunes, UTM-13R-501633E-3532906N (TTU 100170); Cover Sands, UTM-13R-500270E-3532029N (TTU 100171).

Additional records (1): Lewis Well (TTU 20482).

Family Erethizontidae--New World Porcupines

Erethizon dorsatum couesi

North American Porcupine

The porcupine has been steadily expanding it's range eastward into Texas from a single county in the northern Panhandle and the Davis Mountains of the Trans-Pecos in 1905 (Bailey 1905) to it's current distribution covering the western half of the state (Schmidly 2004). In the Guadalupe Mountains, this species is very common and can be

found just about anywhere (Genoways et al. 1979). Scudday (1977) listed this species as occurring in the dunes area and West (1985) reported and apparent carcass in the dunes, of which he photographed but did not collect. No evidence was seen during the current survey of this species, but it most likely maintains a transitory presence.

ORDER CARNIVORA--CARNIVORES

Family Canidae--Dogs

Canis latrans texensis

Coyote

The coyote is widespread throughout the Trans-Pecos, preferring grasslands and desert scrub habitats (Schmidly 1977). Scudday (1977) commonly saw this species in the dune complex and listed it as the most common predator. West (1985) and Stangl (1992) report commonly hearing the distinctive howls and yaps during the evening, as well as noting tracks. No specimens were collected during this survey, but the coyote was often heard both in the mornings and at dusk. Tracks were also found in the intergrade dunes that appeared to be heading toward the Guadalupe Mountains in the east.

Vulpes macrotis neomexicana

Kit Fox

These small foxes are known throughout the Trans-Pecos and prefer open desert or grassland habitats (Schmidly 2004). West (1985) and Stangl (1992) each reported tracks of small canids in the dune complex that most likely belong to this species. Kit foxes have also been seen along U.S. 62/180 to the south of the dune complex (West 1985). Scudday (1977) listed this species along with owls as the predominant predator

on the abundant kangaroo rat population in the area. No specimens of the kit fox were collected during this survey nor were any tracks or other signs observed. A male specimen was collected from near the town of Salt Flat, just to the southwest of the Sand Dune Complex, in July of 1957.

Additional records (1): 4 mi. W of Salt Flat (KUNHM 73922).

Family Mustelidae--Weasels, Badgers, and Otters

Taxidea taxus berlandieri

American Badger

Badgers occur throughout the Trans-Pecos and prefer grassland or desert scrub habitats (Schmidly 1977). No specimens of the badger have been recorded from GMNP but sightings have been reported since 1901 (Bailey 1905, Genoways et al. 1979). Scudday (1977) reported evidence of badger burrowing activity was to be found everywhere. Burrowing evidence was again reported by West (1985), as well as two badger sightings, one near Dell City to the west of the dune complex and another along U.S. 62/180. During this survey, no specimens were collected but evidence of the burrowing activity of this species was present in the cover sand and intergrade dunes areas.

Family Mephitidae--Skunks

Mephitis mephitis varians

Striped Skunk

The striped skunk is ubiquitous in the Trans-Pecos (Schmidly 1977) and southeastern New Mexico (Findley et al. 1975). Genoways et al. (1979) reported that this species could be found anywhere in the park, and Scudday (1977) lists them as occurring

in the sand dune complex. Striped skunks have commonly been seen along U.S. 62/180 to the south of the dune complex (West 1985). No specimens were collected during this survey.

Family Felidae--Cats

Lynx rufus texensis

Bobcat

Bobcats are fairly common throughout the Trans-Pecos and show a decided preference for rocky canyons and cliffs (Schmidly 1977). This species has been reported numerous times from the Guadalupe Mountains to the east of the sand dunes complex (Genoways et al. 1979). Both Scudday (1977) and West (1985) reported feline tracks in the gypsum dunes that they attributed to this species. No evidence of the bobcat was encountered during this survey.

ORDER ARTIODACTYLA--EVEN-TOED UNGULATES

Family Cervidae--Deer

Odocoileus hemionus crooki

Mule Deer

The mule deer occupies almost every habitat type in its range, but prefers more open and arid situations (Schmidly 1977). This species is extremely abundant in the national park, particularly on the mountain slopes (Genoways et al. 1979). Scudday (1977) reported mule deer as “more plentiful than one would expect” and saw several individuals within the gypsum dunes. West (1985) occasionally saw deer tracks in both

the red and gypsum dunes. No specimens were collected during this survey, but deer tracks were seen in the active portion of the gypsum dunes.

SPECIES OF POSSIBLE OCCURRENCE

Fourteen species of mammals representing three orders have been recorded from the national park, but have not been recorded from Sand Dunes Complex. Future research efforts might reveal the presence of these species.

The Guadalupe Mountains provide habitats for several species of bat, any one of which could be using the dune complexes as foraging grounds. Scudday (1977) reported the presence of four species (*Antrozous pallidus*, *Myotis californicus*, *Myotis thysanodes*, and *Pipistrellus hesperus*) utilizing a structure at Ables Well as a night roost. West (1985) noted that the structure was gone and that netting over the well was unproductive. No evidence of chiropteran activity was encountered during the current survey, but bats undoubtedly maintain at least a transient presence as they move from roost sites in the mountains to foraging sites over the agricultural fields near Dell City. Seven of the 13 species recorded from GMNP are listed as highly probable as occurring in the Sand Dunes Complex (*Antrozous pallidus*, *Eptesicus fuscus*, *Myotis californicus*, *Myotis thysanodes*, *Myotis velifer*, *Pipistrellus hesperus*, and *Tadarida brasiliensis*).

Three species of carnivore are suspected of occurring in the Sand Dunes Complex. Gray fox (*Urocyon cinereoargenteus*) are recorded as relatively common throughout the national park, particularly in wooded or canyon situations (Genoways et al. 1979). The raccoon (*Procyon lotor*) is common in wooded areas of the park with a close source of water (Genoways et al. 1979). While there are no scientific records for

the mountain lion (*Puma concolor*) in the national park, there are reports of shootings and sightings throughout the New Mexico portion of the Guadalupe Mountains (Genoways et al. 1979). These species definitely utilize the Guadalupe Mountains to the east and most likely pass through the Sand Dunes Complex during dispersal efforts. Future efforts should reveal the presence of these species.

Four species of rodent possibly occur in the Sand Dunes Complex, but are not currently reported. It is highly likely that the banner-tailed kangaroo rat (*Dipodomys spectabilis*) occurs in the Sand Dunes Complex due to the proximity of records to the southwest and southeast of the area (Genoways et al. 1979, Stangl 1992). The silky pocket mouse (*Perognathus flavus*) occurs in sympatry with its sister species, Merriam's pocket mouse (*Perognathus merriami*), throughout much of the Trans-Pecos (Lee and Engstrom 1991) and could also occur in the Sand Dunes Complex. The rock pocket mouse (*Chaetodipus intermedius*) generally avoids sandy soils but has been caught in the same habitat as the Chihuahuan Desert pocket mouse (*Chaetodipus eremicus*) at several places in the park (Genoways et al. 1979). Scudday (1977) listed the rock squirrel (*Spermophilus variegatus*) as occurring in the dunes area, yet no other specimens or sightings have been found. These last two species are unlikely to be recorded from the Sand Dunes Complex.

COMMUNITY INTERACTIONS

A total of 144 captures were recorded from the Sand Dunes Complex, GMNP, representing seven species of small rodent. Total trap success during this survey was 7.2 percent out of 2000 trap nights. The relative abundances of these seven species can be

broken into four abundance categories: Very Abundant, Abundant, Common, and Uncommon. *Dipodomys merriami* was by far the most abundant small rodent in the Sand Dunes Complex, accounting for roughly 52 percent of the individuals captured, and is the only species that can be considered Very Abundant with a capture index of 0.0380. *Chaetodipus eremicus* is the only species listed as Abundant with a capture index of 0.0205, and accounted for 29 percent of the individuals captured. *Dipodomys ordii* accounted for 13 percent of the total individuals captured, and can be considered a Common species with a capture index of 0.0095. *Neotoma micropus*, *Onychomys arenicola*, *Perognathus merriami*, and *Peromyscus eremicus* each accounted for approximately 1.4 percent of the individuals captured, and are classified as Uncommon with capture indices of 0.0010.

Abundance of small rodents was examined by dune category (Fig. 3). Forty-two individuals representing four species of small rodent were captured in the Red Dunes of the Sand Dunes Complex. Trap success for the Active Dunes was 8.4 percent out of 500 trap nights. The relative abundances of these four species can be broken into four abundance categories: Very Abundant, Abundant, Common, and Uncommon. *Dipodomys merriami* accounted for 50 percent of the individuals captured in the Red Dunes, and is the only species that can be considered Very Abundant with a capture index of 0.0420. *Chaetodipus eremicus* accounted for 36 percent of the captures, and can be considered an Abundant species with a capture index of 0.0120. *Dipodomys ordii* is considered Common in the Red Dunes, with a capture index of 0.0100 and 12 percent of the captures. Only one *Neotoma micropus* was captured from the Red Dunes, and is considered Uncommon for this area.

The White Dunes yielded 30 individuals representing six species of small rodent. Trap success for the White Dunes was 6.0 percent out of 500 trap nights. The relative abundances of these six species can be broken into three abundance categories: Abundant, Common, and Uncommon. *Dipodomys ordii*, accounting for roughly 37 percent of the individuals captured, is the only species that can be considered Abundant with a capture index of 0.0220. *Chaetodipus eremicus* and *Dipodomys merriami* can be considered Common species with capture indices of 0.0160 and 0.0120, respectively. *Onychomys arenicola*, *Perognathus merriami*, and *Peromyscus eremicus* are classified as Uncommon with capture indices ranging from 0.0040 to 0.0020.

Three species represented by 49 individuals were captured in the Cover Sands, yielding a trap success of 9.8 percent out of 500 trap nights. *Dipodomys merriami*, accounting for roughly 74 percent of individuals captured, is classified as Very Abundant with a capture index of 0.0720. *Chaetodipus eremicus*, accounting for 24 percent of the captures, can be considered Abundant with a capture index of 0.0240. Only one *Neotoma micropus* was captured from the Cover Sands, and is considered Uncommon for this area.

The Intergrade Dunes yielded 23 individuals representing four species of small rodent. Trap success for the White Dunes was 4.6 percent out of 500 trap nights. The relative abundances of these four species can be broken into three abundance categories: Very Abundant, Common, and Uncommon. *Dipodomys merriami*, accounting for roughly 57 percent of the individuals captured, is the only species that can be considered Very Abundant with a capture index of 0.0260. *Chaetodipus eremicus* and *Dipodomys ordii* can be considered Common species, with capture indices of 0.0120 and 0.0060,

respectively. Only one *Onychomys arenicola* was captured from the Intergrade Dunes, and is considered Uncommon for this area.

The overall Shannon's Diversity Index for the Sand Dunes Complex, GMNP, was moderate at 0.5450. The diversity indices for the dune categories include a high value for the White Dunes (0.6587), moderate values for the Red Dunes (0.4589) and Intergrade Dunes (0.4669), and a low value for the Cover Sands (0.2825).

Pairwise *t*-tests within the dune categories revealed some significant differences in diversity. Within the dune categories, the White Dunes are significantly more diverse than either the Red Dunes ($P = 0.013$) or the Cover Sands ($P < 0.001$). The Cover Sands are also significantly less diverse than the Red Dunes ($P = 0.012$). The Intergrade Dunes are not significantly different from any of the other dune categories: Red Dunes ($P = 0.947$), White Dunes ($P = 0.320$), and Cover Sands ($P = 0.065$).

DISCUSSION

Fieldwork, museum surveys, and literature searches have recorded the presence of 23 species of mammals occurring within the Sand Dunes Complex, GMNP. These species represent four orders comprised of 5 carnivores, 1 artiodactyl, 15 rodents, and 2 lagomorphs.

The mammalian fauna at Sand Dunes Complex, GMNP, is similar to that of other regions in this part of Texas. Schmidly (1977) reported 96 species of mammals occurring in the Trans-Pecos region of Texas. As expected, all 23 species reported from the Sand Dunes Complex, GMNP, are also listed as occurring in the Trans-Pecos (Schmidly 1977). Genoways et al. (1979) reported 65 species of mammals occurring in GMNP. The only

species occurring in the Sand Dunes Complex that was not listed by Genoways et al. (1979) is *Vulpes macrotis*.

Patterns in how species are distributed in the Sand Dunes Complex begin to emerge through comparing the relative abundances for each species within each dune category. Only three species were encountered in sufficient numbers and from several dune categories to be informative as to the abundance patterns in this area (Fig. 3). *Dipodomys merriami* was the most abundant species and *Chaetodipus eremicus* was second in abundance in the Cover Sands, Intergrade Dunes, and Red Dunes. *Chaetodipus eremicus* has been recorded to prefer sandy soils, whereas *Dipodomys merriami* is much more tolerant in its soil preferences (Schmidly 2004). *Dipodomys merriami* exhibited a preference for the Cover Sands by occupying a much greater portion of the overall rodent population. *Chaetodipus eremicus* was more abundant in the Red Dunes than any other dune category. The White Dunes diverge from the pattern displayed in the other dune categories in that *Dipodomys ordii* supplants *D. merriami* as the most abundant species. Schmidly (2004) states that when these two species occur together in the same area, *D. ordii* will usually prefer sandy soils whereas *D. merriami* will prefer the more firm clay or gravelly soils.

When comparing the diversity values for the four dune categories, a striking pattern emerges. The Cover Sands possess the lowest diversity value and are significantly less diverse than either the Red Dunes or the White Dunes. The White Dunes have the highest diversity value and are significantly more diverse than the Red Dunes, which possess a moderate diversity value. The Intergrade Dunes, however possess a moderate diversity value and are not significantly different than any on the

other dune categories. This implies that the Intergrade Dunes are an area where species transition between the three other dune categories. Indeed, the capture indices for the three informative species are lowest in this dune category.

The zoogeography of the Sand Dunes Complex, GMNP, is similar to that of the Trans-Pecos. Choate (1997) recognized six faunal elements for the mammalian fauna of the Llano Estacado. Based on his results, the mammalian fauna of the Sand Dunes Complex can be assigned to these faunal elements: Chihuahuan, Campestrian, Local, Neotropical, and Widespread.

The Widespread faunal element is comprised of those species with large enough distributions that it is difficult to assign them to any of the other faunal elements. Eleven species (48%) occurring in the Sand Dunes Complex are designated as part of the Widespread faunal element. These species include: *Canis latrans, Erethizon dorsatum, Lepus californicus, Lynx rufus, Mephitis mephitis, Odocoileus hemionus, Peromyscus leucopus, Peromyscus maniculatus, Procyon lotor, Sigmodon hispidus,* and *Taxidea taxus*. Choate (1997) determined that this faunal element accounts for 36 percent of the species occurring on the Llano Estacado, while it accounts for 29 percent of the species in the Trans-Pecos (Schmidly 1977).

The Chihuahuan faunal element contains species with distributions centered in the Mexican states of Chihuahua, Coahuila, and Durango. Ten of the species occurring at the Sand Dunes Complex are included in the Chihuahuan faunal element as follows: *Chaetodipus eremicus, Cratogeomys castanops, Dipodomys merriami, Neotoma leucodon, Onychomys arenicola, Peromyscus eremicus, Reithrodontomys megalotis, Spermophilus spilosoma, Sylvilagus audubonii*, and *Vulpes macrotis.* The Chihuahuan

faunal element accounts for 44 percent of the faunal composition in the dunes area. Choate (1997) found that 17 percent of the Llano Estacado species originated from the Chihuahuan faunal element. In the Trans-Pecos, this faunal element comprises 19 percent of the mammals (Schmidly 1977).

The Campestrian faunal element contains species with distributions centered on the Great Plains of North America. *Dipodomys ordii* is the only species (4%) from the Campestrian faunal element that occurs in the dunes area. Six percent of the mammals in the Trans-Pecos originate from the Campestrian faunal element (Schmidly 1977), while 12 percent of the species on the Llano Estacado are from this faunal element (Choate 1997).

The Neotropical faunal element is comprised of species with distributions centered in southern Mexico and Central America. Two species in the Sand Dunes Complex (9%) are included in the Neotropical faunal element as follows: *Neotoma micropus* and *Perognathus merriami*. In the Trans-Pecos, this faunal element accounts for six percent of species (Schmidly 1977), and for eight percent of the species occurring on the Llano Estacado (Choate 1997).

The mammalian fauna of the Sand Dunes Complex, GMNP, is composed primarily of Widespread species with a strong influence from the Chihuahuan faunal element, whose species comprise 84 percent of the rodent population. The two most abundant rodents are *Dipodomys merriami* and *Chaetodipus eremicus*, both Chihuahuan in origin. These zoogeographic affinities demonstrate that the sand dunes area has a high affinity to the Chihuahuan desert and the rest of the Trans-Pecos region of Texas.

ACKNOWLEDGMENTS

This study was funded through a grant from the Chihuahuan Desert Network, National Park Service. We appreciate the assistance and patience of Bill Reid and Fred Armstrong, as well as their knowledge of Guadalupe Mountains National Park. Dnate Baxter, Rex McAliley, Heather Meeks, Noe de la Sancha, Vicki Swier, and Ray Willis assisted with field collection and specimen preparation.

Thanks to these museums and museum personnel for providing lists of current holdings in their respective institutions of mammals from Hudspeth and Culberson counties, Texas: Thorvald Holmes at the University of Kansas Natural History Museum (KUNHM); Robert Baker and Heath Gardner at The Museum of Texas Tech University (TTU); and Robert Fisher at the United States National Museum of Natural History (USNM).

LITERATURE CITED

Animal Care and Use Committee. 1998. Guidelines for the capture, handling, and care of mammals as approved by the American Society of Mammalogists. Journal of Mammalogy, 79(4):1416-1431.

Bailey, V. 1905. Biological survey of Texas. North American Fauna, 25:1-222.

Baker, R. J., L. C. Bradley, R. D. Bradley, J. W. Dragoo, M. D. Engstrom, R. S. Hoffmann, C. A. Jones, F. Reid, D. W. Rice, and C. Jones. 2003. Revised checklist of North American mammals north of Mexico, 2003. Occasional Papers, the Museum, Texas Tech University, 229:1-23.

Brand, J. P., and A. D. Jacka. 1979. Geology of the Guadalupe Mountains National Park. in: Genoways, H. H., and R. J. Baker (eds). Biological Investigations in the Guadalupe Mountains National Park, Texas. National Park Service, Proceedings and Transactions Series Number Four.

Conroy, M. J. 1996. Abundance indices. Pp. 179-192 *in*: Measuring and monitoring biological diversity: standard methods for mammals. Wilson, D. E., F. R. Cole, J. D. Nichols, R. Rudran, and M. S. Foster, eds. Smithsonian Institution Press, Washington, D. C. 409 pp.

Cornely, J. E. 1979. Ecological distribution of woodrats (Genus *Neotoma*) in Guadalupe Mountains National Park, Texas. in: Genoways, H. H., and R. J. Baker (eds). Biological Investigations in the Guadalupe Mountains National Park, Texas. National Park Service, Proceedings and Transactions Series Number Four.

Cornely, J. E., D. J. Schmidly, H. H. Genoways, and R. J. Baker. 1981. Mice of the genus Peromyscus in Guadalupe Mountains National Park, Texas. Occasional Papers, the Museum, Texas Tech University, 74:1-35.

Davis, W. B. 1940. Mammals of the Guadalupe Mountains of western Texas. Occasional Papers of the Museum of Zoology, Louisiana State University, 7:69-84.

Findley, J. S., A. H. Harris, D. E. Wilson, and C. Jones. 1975. Mammals of New Mexico. University of New Mexico Press, Albuquerque, New Mexico. 360 pp.

Gehlbach, F. R. 1967. Vegetation of the Guadalupe escarpment, New Mexico-Texas. Ecology, 48:404-419.

Genoways, H. H., and R. J. Baker (eds). 1979. Biological Investigations in the Guadalupe Mountains National Park, Texas. National Park Service, Proceedings and Transactions Series Number Four.

Genoways, H. H., R. J. Baker, and J. E. Cornely. 1979. Mammals of the Guadalupe Mountains National Park, Texas. Pp. 257-270 in: Genoways, H. H., and R. J. Baker (eds). Biological investigations in the Guadalupe Mountains National Park, Texas. National Park Service, Proceedings and Transactions Series Number Four.

Hall, E. R. 1981. The mammals of North America. John Wiley & Sons, Inc., New York, 1-1181 + 90 pp.

Jones, C., W. J. McShea, M. J. Conroy, and T. H. Kunz. 1996. Capturing mammals. Pp. 115-155 *in*: Measuring and monitoring biological diversity: standard methods for mammals. Wilson, D. E., F. R. Cole, J. D. Nichols, R. Rudran, and M. S. Foster, eds. Smithsonian Institution Press, Washington, D. C. 409 pp.

Lee, T. E., Jr., and M. D. Engstrom. 1991. Genetic variation in the silky pocket mouse (*Perognathus flavus*) in Texas and New Mexico. Journal of Mammalogy, 72:273-285.

Machenberg, M. D. 1984. Geology of Monahans Sandhills State Park, Texas. Bureau of Economic Geology, University of Texas at Austin, Guidebook 21:1-39.

Schmidly, D. J. 1977. The mammals of Trans-Pecos Texas. Texas A&M University Press: College Station. 225 pp.

Schmidly, D. J. 2004. The mammals of Texas. Revised Edition. Texas Parks and Wildlife Press, Austin. 501 pp.

Scudday, J. F. 1977. The vertebrate fauna of the Salt Flats area, Hudspeth County, Texas. A natural area survey, Gypsum Dunes. Division of Natural Resources and Environment. University of Texas at Austin.

Stangl, F. B., Jr. 1992. Report on the mammals of the gypsum dunes preserve, Hudspeth County, Texas. Report to the Texas Chapter of the Nature Conservancy.

Stangl, F. B., Jr., W. W. Dalquest, and R. R. Hollander. 1994. Evolution of a desert mammalian fauna: a 10,000 year history of mammals in Culberson and Jeff Davis counties, Trans-Pecos Texas. Midwestern State University Press, Wichita Falls, Texas, 264 pp.

Wauer, R. H., and D. H. Riskind (eds). 1977. Transactions-Symposium on the Biological Resources of the Chihuahuan Desert Region, U. S. and Mexico. National Park Service, Washington, D.C.

West, S. 1985. Vertebrate fauna of the Gypsum Dunes and surrounding desert grassland, Hudspeth County, Texas. Unpublished manuscript.

Wilhelm, D. E., Jr. 1982. Zoogeographic and evolutionary relationships of selected populations of Microtus mexicanus. Occasional Papers, the Museum, Texas Tech University, 75:1-30.

Wilkins, D. E., and D. R. Currey. 1999. Radiocarbon chronology and carbon isotope analysis of mid-to late-Holocene Aeolian environments, Guadalupe Mountains National Park, Texas, USA. The Holocene, 9.3:363-371.

Wilson, D. E., and F. R. Cole. 2000. Common names of mammals of the world. Smithsonian Institution Press, Washington, D. C. 204 pp.

Fig. 1. Map showing the location of the Sand Dunes Complex, Guadalupe Mountains National Park, in Hudspeth County, Texas.

Fig. 2. Map of the Sand Dunes Complex showing general reference landmarks and collecting localities.

Fig. 3. The capture indices for seven species of rodents by dune category from the Sand Dunes Complex, Guadalupe Mountains National Park.

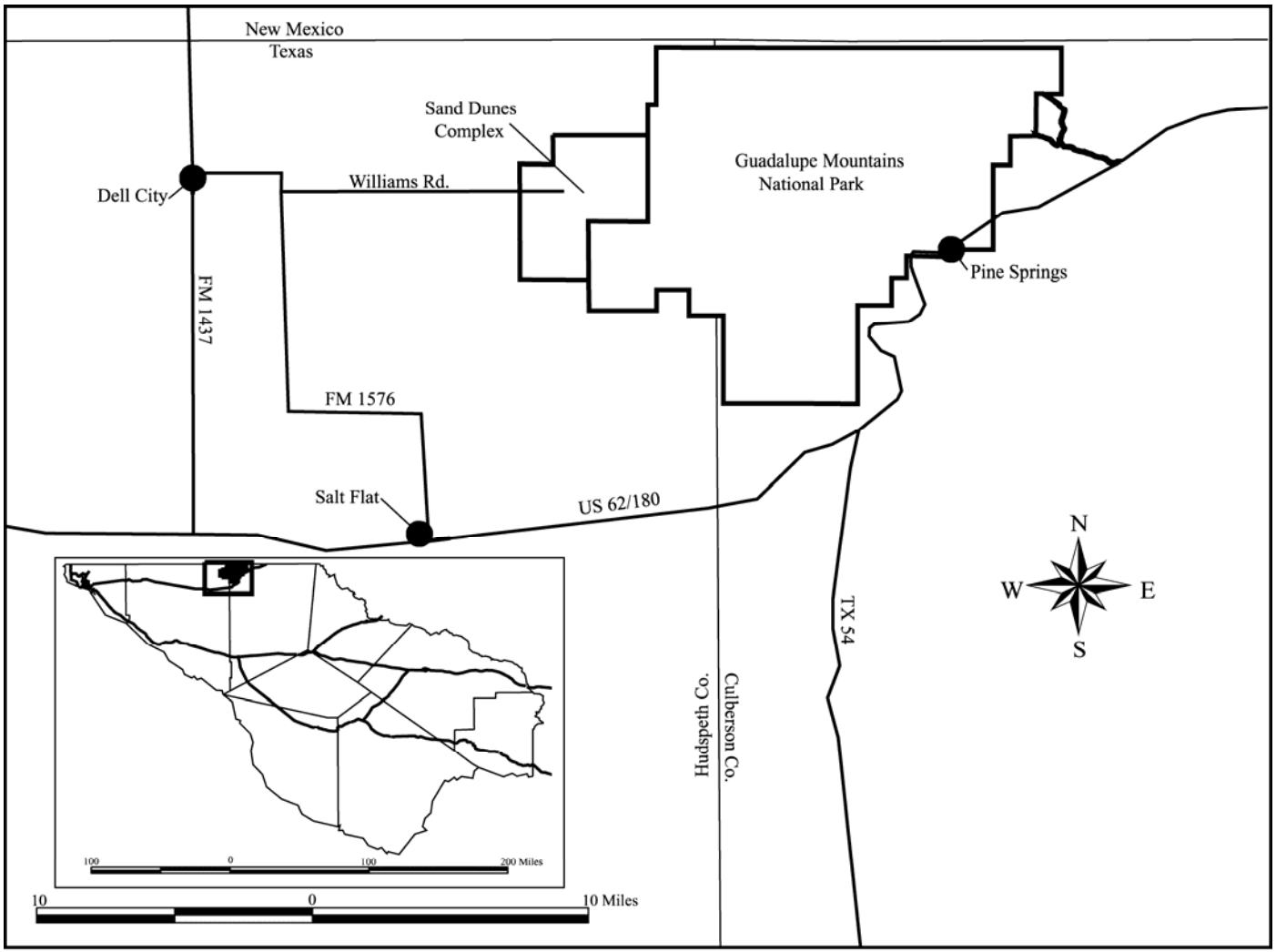

Fig. 1. Map showing the location of the Sand Dunes Complex, Guadalupe Mountains National Park, in Hudspeth County, Texas.

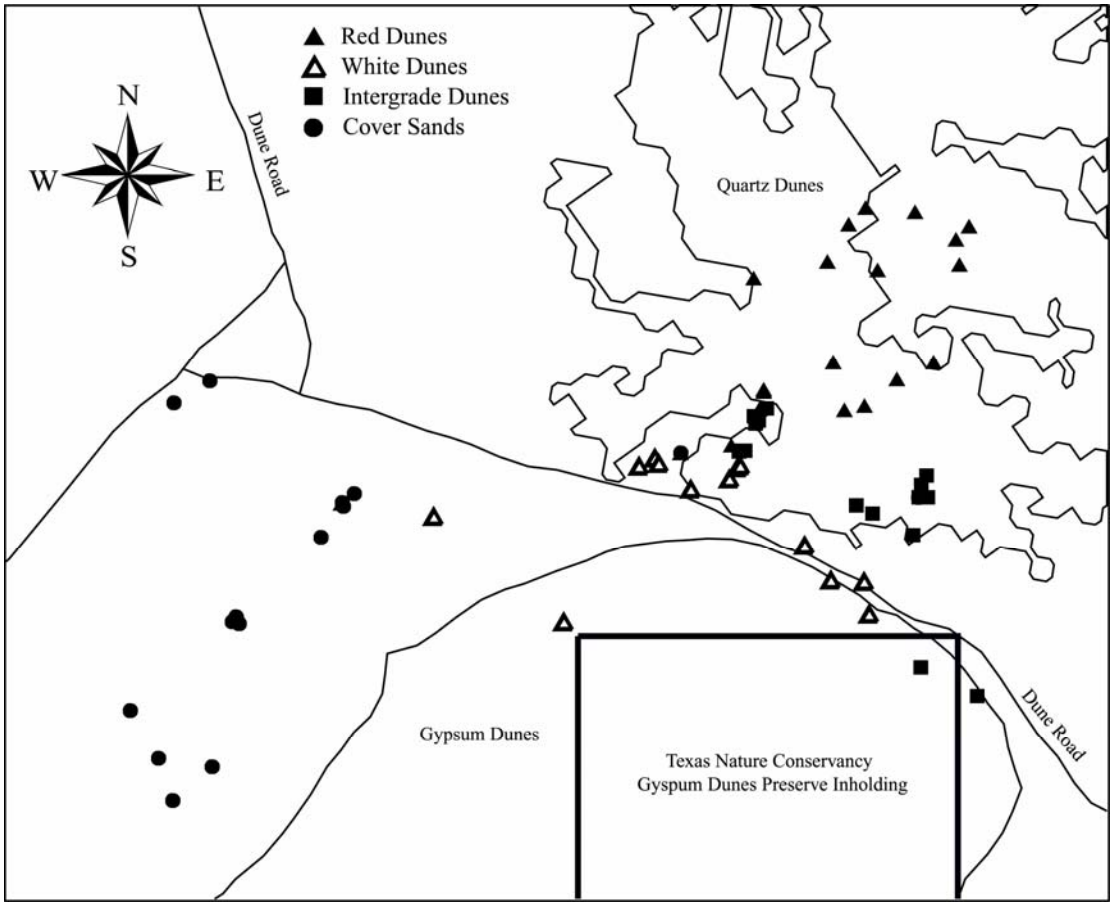

Fig. 2. Map of the Sand Dunes Complex showing general reference landmarks and collecting localities.

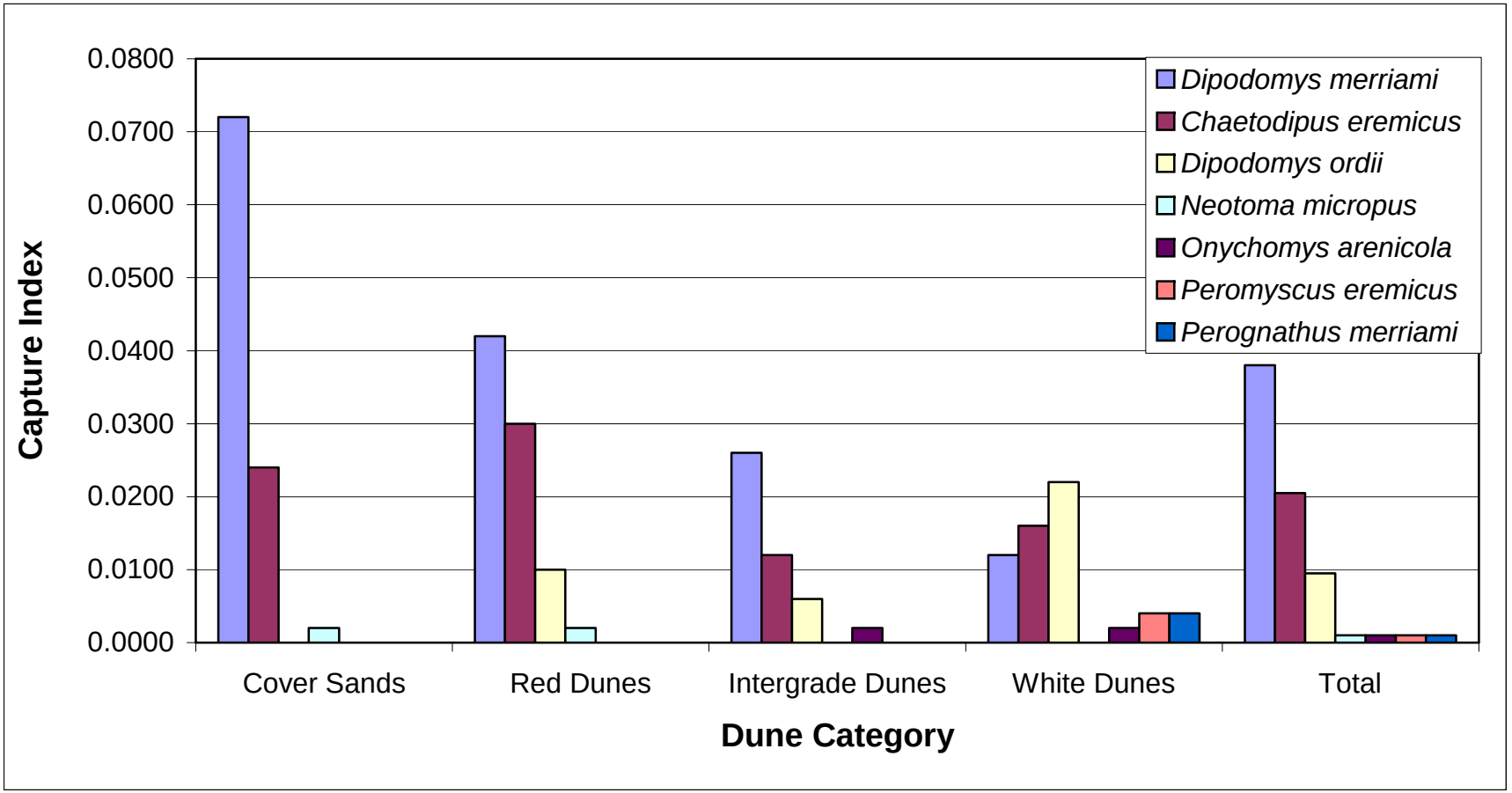

Fig. 3. The capture indices for seven species of rodents by dune category from the Sand Dunes Complex, Guadalupe Mountains National Park.